

Research Hotspots and Trends in Puerperal Infection: A Bibliometric Analysis

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Keywords: Pregnant Women; Puerperal Infection; Bibliometric Analysis; Trends; Research Hotspots

Abstract: This study aimed to comprehensively identify the research hotspots, current status, and developmental trends of puerperal infection from January 1, 2013, to December 31, 2023. We used the China National Knowledge Infrastructure and Web of Science Core Collection as the data source, both English and Chinese literature related to puerperal infection published during this period were retrieved. Visual analyses were conducted on annual publication output, national and institutional co-authorship networks, co-author and co-citation relationships, keyword co-occurrence, keyword clustering, and the keyword bursting. A total of 484 English and 594 Chinese articles were included. The number of publications on puerperal infection exhibited a generally steady yet fluctuating upward trend. The United States ranked first in publication volume and has the highest total link strength. Duke University was the research institution with the highest volume of publications. The research hotspots included puerperal infection, cesarean section, antibiotic prophylaxis, and risk factors. Inflammatory factors, drug resistance, wound infection, and postpartum hemorrhage represented emerging research frontiers. Overall, the field of research on puerperal infections both domestically and internationally is generally in the developmental stage. In the future, Chinese medical staff should align their work with national healthcare priorities, strengthen collaborations across institutions, regions, and countries, and further advance research on puerperal infection to safeguard women's health.

1. Introduction

Puerperal infection refers to local or systemic infections caused by pathogens that invade the reproductive tract during delivery and the period of puerperium. It can trigger systemic inflammatory response and multiple organ dysfunction syndrome, adversely impacting maternal prognosis and recovery^[1]. It is one of the major causes of maternal mortality and may indirectly affects newborns^[2]. Puerperal infections progress rapidly. Mild cases may present only with increased vaginal discharge, while severe cases can trigger a series of systemic diseases such as sepsis, vulvitis, septicemia, septic shock, and multiple organ dysfunction syndrome. These complications can result in maternal mortality, intrauterine fetal death, preterm birth, and early neonatal death, posing a threat to the health

and lives of both mothers and newborns^[3]. Puerperal infections also negatively affect the maternal mental health and neonatal health and survival. They may cause feelings of unease, anxiety, and depression, which increase the psychological burden on mothers^[4].

The incidence of puerperal infection is 1%~7.2%, which is one of the most common complications in women and an important cause of perinatal mortality in newborns^[5]. Research has found that women with diabetes or a history of diabetes have impaired immune function, leading to an increased risk of puerperal infection during the puerperium^[6]. The high glucose environment provides a bacterial colonization, increasing susceptibility to puerperal infections^[7]. Cesarean section is an invasive surgical procedure, and microorganisms can enter the body through the reproductive tract, leading to postoperative puerperal infection^[8]. The World Health Organization(WHO) recommends that the cesarean section rate be controlled below 10%~15%^[9], but relevant survey results show that the cesarean section rate of primiparous women in our country is as high as 50.4%^[10]. Following 2016 the two-child policy implemented, the number of women undergoing second cesarean sections has significantly increased. Compared with women experiencing their first pregnancy or those with previous vaginal deliveries, nearly all women who had a prior cesarean section undergo another cesarean in subsequent pregnancies. Women with a history of cesarean section also faces elevated risk of placenta previa and postpartum hemorrhage, thereby substantially elevating their risk of puerperal infection^[11].

CiteSpace^[12] was introduced into China in 2005 by Professor Chen Chaomei and his team. The software enables researchers to visually analyze the current state and hotspots of research within a specific field through graphical representations, and to uncover relationships among authors, institutions, countries, keywords, and citations. VOSviewer^[13], developed by the Leiden University Center for Science and Technology Studies, enables researchers to clearly visualize the strength of interrelationships among keywords within a specific research field.

The WHO has emphasized the importance of strengthening early screening for perinatal infections, improve antimicrobial strategies, standardize the use of antibiotics. It has proposed systematic recommendations for the prevention and management of perinatal infections to reduce maternal and infant morbidity and mortality caused by such infections^[14]. Therefore, to better implement the above international policy directions, identify gaps between research and practice, and provide evidence-based support for future interventions, it is necessary to systematically understand the current state of research, academic collaboration networks, and key research areas in this field. This study employs bibliometric methods, utilizing CiteSpace and VOSviewer to visualize the field, with the aim to analyze its research hotspots and development trends.

2. Materials and Methods

2.1 Data Sources and Retrieval Strategy

This study primarily utilized literature indexed in the China National Knowledge Infrastructure (CNKI) and the Web of Science Core Collection (WoS) as data sources, with separate analyses of Chinese and English-language articles. A subject search was performed in the WoS using the keywords such as “puerperal infection,” “puerperal sepsis,” and “postpartum sepsis,” and in the CNKI using the keywords “postpartum infection” and “puerperal infection.” The search period spanned January 1, 2013, to December 31, 2023. Results were exported in plain text format, yielding a total of 484 English-language and 594 Chinese-language articles.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria: (1) Publicly published literature in Chinese and English literature; (2) Research

topic focused on puerperal infection.

Exclusion Criteria: (1) Duplicate publication; (2) Literature derived from editorial materials, case studies, abstract publications, conference proceedings, revisions, letters, briefings, news and book reviews; (3) Retracted literature.

2.3 Analytical Methods

The visualization and bibliometric analyses were conducted using CiteSpace (version 6.1.R6), VOSviewer (version 1.6.20), and Scimago Graphica (version 1.0.38). CiteSpace was used to generate keyword co-occurrence networks, keyword burst analysis, and clustering analyses to identify the frontiers of this research field. The parameter settings were as follows: time span from 2013 to 2023, slice year set to 1, with all other parameters left at their default values. After configuration, visual analyses of annual publication volume and keywords were performed, and keyword bursts and clusters were explored. VOSviewer was used to analyze publication volume and collaboration levels by country/region, institution, and author. By utilizing VOSviewer in conjunction with Scimago Graphica to visualize national/regional research institutions and their collaborative relationships, personalized maps were generated. After running the software, the parameters and positions of nodes and connections in the visualization diagram were progressively adjusted to achieve clarity and visual appeal, ultimately presenting the research through a visualized diagram.

3. Results

3.1 Annual Publication Volume

A total of 847 English-language and 985 Chinese-language records were retrieved. According to the inclusion criteria, 484 English-language and 594 Chinese-language articles were ultimately included. As shown in Figure 1, which depicted the trend of annual publications on puerperal infections, the average annual number of publications in China was approximately 59, with a gradual slowdown observed over the past three years. In contrast, international publications averaged 49 articles per year, showing an overall upward trend.

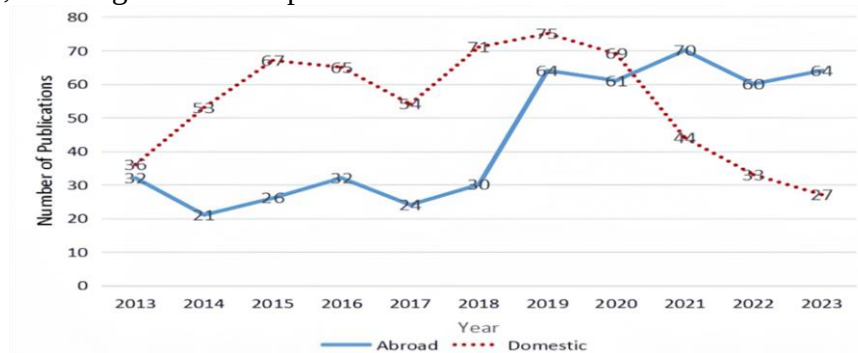


Figure 1: Trend of annual publications on puerperal infections in China and abroad.

3.2 National /Regional Research Institutions and Their Collaborative Relationships

Collaboration networks among countries and regions were analyzed by importing data from VOSviewer into Scimago Graphica. As shown in the co-authorship network map (Figure 2), the total link strength value indicates the level of collaboration among scholars. The country with the highest overall link strength was the United States, indicating that American scholars demonstrate a high level of attention and research interest in this field. Between 2013 and 2023, researchers from 89 countries and regions published articles on puerperal infections. The United States, China, India, the

United Kingdom, and Pakistan were the top five countries in terms of the number of articles published in this field. Moreover, this field encompassed 300 institutions, with the most prolific contributors being Duke University (n=17, 3.72%), Aga Khan University (n=10, 2.19%), and Guangzhou Medical University (n=7, 1.53%). The majority of publications originated from research institutions and universities. Overall, research articles on puerperal infections primarily focused on North America, Western Europe, and China.



Figure 2: Co-authorship of Web of Science puerperal infections by country/region from 2013 to 2023.

3.3 Analysis of Authors and Collaborative Relationships

Domestically, the top three authors by publication volume were Ren Yuejiao (n=2), Guan Hongqiong (n=2), and Liu Na (n=2). Internationally, the top three authors by publication volume were Dotters-Katz, Sarah K (n=4), Denoble, Anna E (n=3), and Ariff, Shabina (n=3). Overall, their contributions to the total publication volume remained relatively low. As shown in Figure 3, which depicts the collaborative network of authors publishing on puerperal infections, a collaborative network was formed around Dotters-katz, Sarah K, Denoble, Anna E, Ariff, Shabina, Farkash, Rivka, and Dotters-katz, Sarah K, with most scholars engaging in frequent collaboration.

Most domestic scholars publish relatively few publications, and their level of collaboration was not as frequent as that observed internationally. According to Price's Law, the number of publications (N) by core authors must satisfy $N \approx 0.749 \times \sqrt{n_{\max}}$, where $n_{\max}$ is the number of publications by the most prolific author within the statistical period. Based on the statistical data in this study, the publication volume of foreign core authors should satisfy $N \approx 1.5$. Following the rounding principle, authors with 2 or more publications were classified as core authors, totaling 61 individuals. The most prolific author was Dotters-Katz, Sarah K, who published a total of 4 publications.

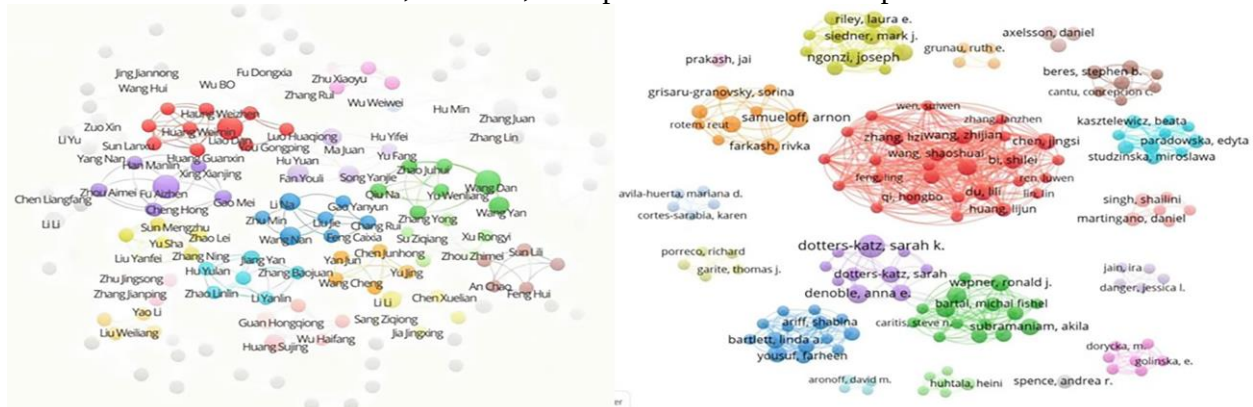


Figure 3: Collaborative network of authors publishing on puerperal infections.

3.4 Keyword Co-occurrence

Keywords represent the author's highly condensed and summarized interpretation of the article's content, reflecting the core essence of the literature. The higher their frequency of appearance, the greater the research interest they indicate. High-frequency keywords reflect the hot topics in this research field. Selecting “keyword” as the node type in the CiteSpace interface generates a keyword co-occurrence map. Figure 4 shows keyword co-occurrence map on puerperal infections. The most frequently occurring keywords in the field of puerperal infection research abroad were, in descending order: women, risk factor, risk, puerperal sepsis, and pregnancy. The most frequently occurring keywords in China were, in descending order: puerperal infection, cesarean section, puerperium, risk factors, and infection.

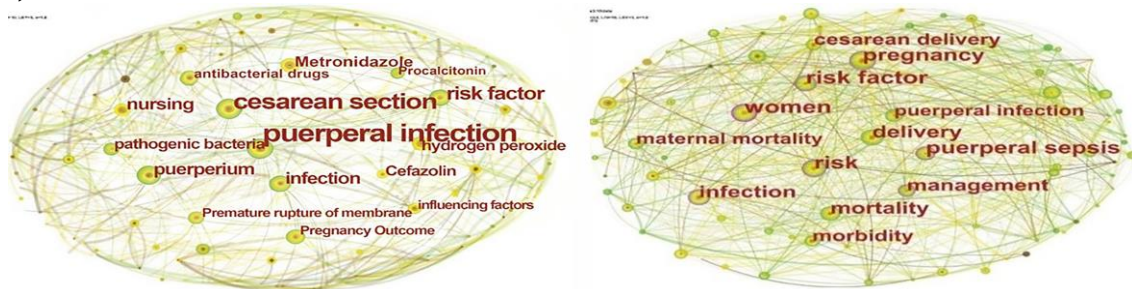


Figure 4: Keyword co-occurrence map on puerperal infections.

3.5 Keyword Clustering

Keyword clustering analysis enables the identification and interpretation of various research themes within a specific field of study. The Log-Likelihood Ratio (LLR) algorithm in CiteSpace was applied to group identical or similar subject terms, generating a keyword clustering map (Figure 5). Five tags were selected to represent five clusters. The top three clusters in the domestic research field were #0 Puerperal Infection, #1 Cesarean Section, and #2 Hydrogen Peroxide. The module value (Q-value) was 0.5507 (>0.3), and the average silhouette value (S-value) was 0.8364 (>0.7). The top three clusters in the international research domain were #0 antibiotic prophylaxis, #1 risk factor, and #2 group A streptococcus. The module value (Q-value) was 0.5397 (>0.3), and the average silhouette value (S-value) was 0.7734 (>0.7), indicating excellent clustering performance.

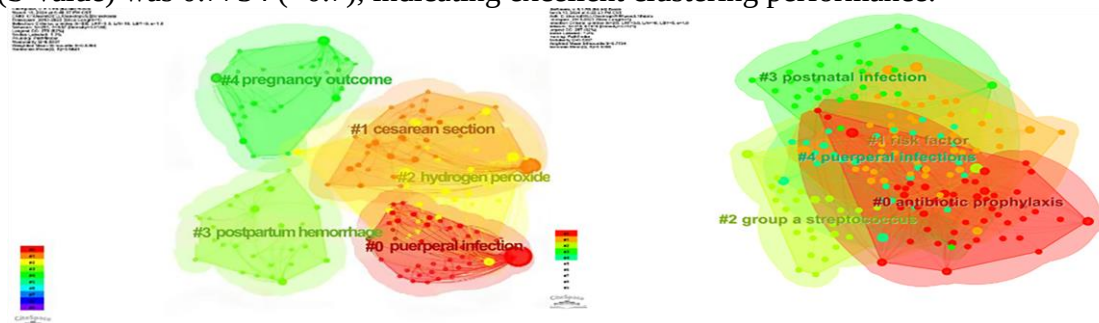


Figure 5: Keyword clustering of puerperal infections.

3.6 Keyword Burst Analysis

Keyword burst analysis refers to the phenomenon where keyword appears with exceptionally high frequency over a period of time, enabling the prediction of development trends and research frontiers within a specific field. In this study, by setting γ to 0.7 via the control panel, a total of 10 keyword burst were obtained. Figure 6 shows the keyword burst map for puerperal infections, depicting the changes in emerging keywords from 2013 to 2023. Based on burst intensity, the keywords with the

highest salience intensity in the left panel were “treatment” and “nursing,” while the keywords with the highest salience intensity in the right panel were “transmission” and “preterm infant.” From 2019 to 2023, inflammatory mediators, antibiotic resistance, wound infection, and postpartum hemorrhage represented the research frontiers in this field.

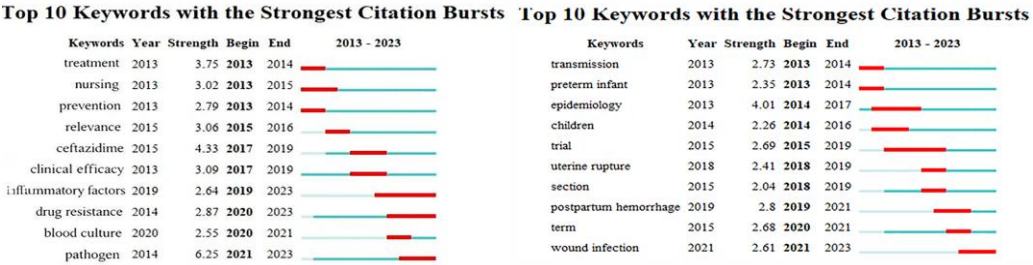


Figure 6: Keyword burst map of puerperal infections.

4. Discussion

4.1 Analysis of Trends in Puerperal Infections

An analysis of the literature on puerperal infections from the CNKI and Web of Science Core Collection databases revealed that from 2013 to 2023, the number of studies increased steadily over time, indicating that puerperal infection has consistently been a topic of interest among scholars both domestically and internationally in the medical field. However, the publication volume from overseas was slightly lower than that from domestic sources. This discrepancy may be related to the fact that all the literature included in this study was in English, thereby introducing potential language bias. In addition, cultural differences and variations in healthcare systems between countries may also contribute to this disparity. In China, due to the traditional concept of fertility, puerperal infection-related issues may receive more attention, so related research and practice are more in-depth and extensive. In contrast, in many Western countries, advanced medical technology and comprehensive puerperal care and infection prevention measures have contributed to lower infection rates, resulting in fewer research publications in this field. Nevertheless, the number of publications is only one aspect of measuring the research activity of a field, and does not fully represent the level and quality of research in that field.

4.2 Analysis of Publishing Countries, Institutions, and Authors

This study analyzed the research status puerperal infections among countries and institutions based on publication volume. The findings revealed that the United States led in the number of publications and demonstrated the highest overall connectivity strength, with Duke University ranking first among institutions in terms of publication output. Core authors played a leading role in guiding the development of the field. Researchers such as Dotters-katz. Sarah K.; Denoble. Anna E.; Ariff, Shabina; and Farkash. Rivka have formed a highly concentrated and relatively stable collaborative network. In contrast, domestic scholarly collaboration networks displayed pronounced regional characteristics and relatively low concentration levels. While Chinese research teams collaborated actively within their own institutions, cross-group and cross-institutional cooperation remained limited. In terms of institutional affiliation, authors of English-language literature were primarily based in universities, while authors of Chinese-language literature were mostly affiliated with hospitals. Hospital research tended to focus more on clinical practice, while university research focused more on theoretical frameworks. Both of domestic and international scholars should further strengthen communication and collaboration, promote cooperation between university research

centers and hospital clinical platforms, and foster multidisciplinary and multi-institutional partnerships to advance large-scale research on puerperal infections and related topics.

4.3 Research Hotspots and Frontiers in Puerperal Infections

4.3.1 Research Hotspots

Based on co-occurrence and clustering analysis of keywords, domestic research on puerperal infections primarily focused on puerperal infections and cesarean sections, whereas international research centered on antibiotic prophylaxis and risk factors.

According to WHO, infections (primarily puerperal), severe hemorrhage (primarily postpartum hemorrhage), pregnancy-induced hypertension (preeclampsia and eclampsia), and childbirth complications and unsafe abortions accounted for nearly 75% of all maternal deaths^[15]. During childbirth, the maternal body experiences heightened stress responses and reduced immune function, which predisposing to reproductive tract injuries and subsequent infection^[16]. In severe cases, this may progress to puerperal sepsis, posing a life-threatening risk to the mother. Several studies have found that cesarean section, gestational anemia, and delayed postpartum hemorrhage are associated factors for puerperal infection^[17,18]. Cesarean section is a well-recognized risk factor for puerperal infection, particularly in emergency procedures. The 2023 Expert Consensus on Cesarean Section Surgery reported that the cesarean section rate in China's secondary and higher-level hospitals reached 44.1% in 2020^[19]. With the ongoing healthcare reform, laws and regulations governing cesarean sections are being continuously refined. The government has implemented a series of policies to encourage medical institutions to promote natural childbirth and reduce the cesarean section rate. Moreover, relevant laws and regulations also stipulate the approval procedures and oversight mechanisms for cesarean section surgeries to ensure their safety and effectiveness. The implementation of these laws and regulations has improved the quality of cesarean section procedures and promoted the rational utilization of medical resources. Therefore, medical staff should rigorously adhere to the indications for cesarean section, exercise prudent judgment based on actual circumstances, reduce the risk of puerperal infection to safeguard maternal and neonatal health.

Antibiotic prophylaxis remains an essential role in cesarean sections and during the perioperative period. Moulton et al.^[20] found that although the overall incidence of postpartum endometritis was low, it was closely linked to preoperatively diagnosed chorioamnionitis. Duffy et al.^[21] observed that inadequate surgical antibiotic prophylaxis was associated with an increased risk of surgical site infection but was not directly linked to postpartum endometritis. Furthermore, research by Venkatesh et al.^[22] indicates that among cesarean section patients treated for chorioamnionitis, antibiotic regimens that combine cefazolin with conventional clindamycin or metronidazole significantly reduce the risk of puerperal infections, particularly surgical site infections. The risk factors for infection after cesarean section are complex, and multiple factors need to be considered for prevention and treatment, and further in-depth research is needed in the future to clarify the specific impact of different factors on infection after cesarean section and explore more effective antibiotic prevention and treatment strategies.

4.3.2 Research Frontiers

Based on the results of this study's keyword burst analysis, domestic research on puerperal infections will continue to deepen in the areas of “inflammatory mediators” and “drug resistance,” while international studies focus primarily on wound infection and postpartum hemorrhage.

Inflammatory factors have shown important value in the early diagnosis of puerperal infections. Research has shown^[23] that the urinary tract, pelvic cavity, and uterine incision sites are prone to

puerperal infections, with significantly elevated levels of inflammatory factors following infection. In the early diagnosis of puerperal infections following cesarean sections, alterations in peripheral blood levels of ApoE, NF- κ B mRNA, and TLR-4 mRNA can reflect early signs of infection^[24], providing diagnostic evidence for initiating therapeutic interventions. Puerperal infection following premature rupture of membranes is influenced by multiple independent risk factors, such as the duration of membrane rupture, genital tract infection, concomitant gestational hypertension, concomitant gestational diabetes, and postpartum hemorrhage. Variations in inflammatory biomarkers such as IL-6, TAC, and MPO show important predictive value for puerperal infections. Elevated levels of these inflammatory biomarkers in patients provide crucial diagnostic reference for the disease. Therefore, when selecting antimicrobial agents, clinicians should fully consider resistance profiles and prioritize drugs with high sensitivity to ensure therapeutic efficacy.

A decade-long study by Saeed et al.^[25] found that hematoma was most closely associated with surgical site infection at the incision site. Cesarean section is the most significant risk factor for puerperal infection. Kvalvik et al.^[26] conducted a case-control study at H kland University Hospital, which revealed that emergency cesarean sections carry a significantly higher risk of surgical site infection compared to elective cesarean sections. Pre-pregnancy obesity, pre-existing mental illness, and blood transfusions during or after delivery also been identified as independent risk factors for surgical site infections. A study^[27] found that preoperative vaginal cleansing with povidone-iodine significantly reduced the incidence of maternal infections following composite cesarean sections compared to immediate postoperative use, particularly in women with ruptured membranes and emergency cesarean sections. The incidence of surgical site infections (SSI) following cesarean sections ranges from approximately 5% to 10%. Ben Shoham et al.^[28] found that the timing of prophylactic antibiotic administration (before surgical incision versus after umbilical cord clamping) did not significantly affect the reduction in SSI infection rates. Therefore, for women with these risk factors, clinical healthcare providers should pay particular attention, implement proactive and effective preventive measures, and closely monitor for potential signs of infection to ensure the safety of both mother and infant and reduce the risk of infection.

Postpartum hemorrhage is another factor influencing puerperal infection in patients undergoing cesarean section. The WHO report noted^[15] that in low-income countries, postpartum hemorrhage is the leading cause of maternal mortality and accounts for nearly one-quarter of all maternal deaths globally. Postpartum hemorrhage can be prevented and treated, yet approximately 70,000 women still die from it each year. Guo et al.^[29] found that uterine gauze packing demonstrated superior efficacy compared to uterine balloon packing in treating postpartum hemorrhage following cesarean section, without increasing the risk of potential puerperal infection. This method may be recommended as a routine treatment for patients with postpartum hemorrhage unresponsive to conventional basic therapy. The 2022 FIGO Guidelines for the Management of Postpartum Hemorrhage^[30] recommend that oxytocin is the first-line medication for preventing postpartum hemorrhage. Furthermore, a meta-analysis by AL-Dardery et al.^[31] further confirmed the significant efficacy of tranexamic acid in reducing total maternal blood loss and preventing postpartum hemorrhage. For both cesarean sections and vaginal deliveries, tranexamic acid effectively reduces total maternal blood loss and decreases the incidence of postpartum hemorrhage. Medical staff should closely monitor the patient's physical condition and promptly adjust the mother's physical state and immune function to reduce the risk of infection.

The occurrence of puerperal infection is characterized by the interaction of multiple factors, and there are differences in the focus of risk factor research both domestically and internationally. Overseas research focused on the role of chronic inflammatory diseases and immune mechanisms. A study found that Crohn's disease, disease activity, and immunosuppressive therapy are major risk factors for puerperal incisional infection and delayed wound healing, while the use of biologics during

the perinatal period does not significantly increase the risk of infection^[32]. Domestic research focused on clinical factors related to pregnancy and childbirth, including anemia, premature rupture of membranes, chorioamnionitis, pregnancy-related complications, and procedural interventions such as cesarean sections and episiotomies. Both domestic and international studies point out that cesarean section is the core high-risk factor for puerperal infection, which suggests that preoperative risk assessment, perioperative infection prevention and control and individualized management strategies should be strengthened to reduce the incidence of puerperal infection.

5. Conclusion

This study utilized VOSviewer and CiteSpace software to identify research hotspots and trends in puerperal infection studies. Nonetheless, Due to the relatively single database selected for inclusion, there may be problems of incomplete literature analysis and potential omissions, and there may be insufficient number of articles, which may cause errors in the analysis results. Future studies should incorporate multiple databases such as Embase and PubMed to ensure more objective and credible research findings. Due to limitations in the timeframe for literature inclusion, the latest articles included to CNKI and the WoS Core Collection were not analyzed. Therefore, ongoing quantitative analysis of literature across different databases will be conducted to identify real-time hotspots and accurately track research trends. In the future, Chinese medical professionals should conduct research on puerperal infections tailored to national healthcare contexts. Efforts must be made to strengthen cooperation and exchanges across agencies, regions, and borders through a variety of methods, and promote interdisciplinary alliances to improve maternal health and safeguard the welfare of women.

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